2017 NMC Technology Outlook

Chinese Higher Education

A Horizon Project Regional Report

2017 NMC Technology Outlook > Chinese Higher Education at a Glance

Key Trends Accelerating Technology Adoption in Chinese Higher Education

2017 2018 2019 2020 2021

Short-Term
Driving technology adoption in Chinese Higher Education over the next one to two years

- Increasing Use of Blended Learning Designs
- Proliferation of Open Educational Resources
- Rise of STEAM Learning

Mid-Term
Driving technology adoption in Chinese Higher Education over the next three to five years

- Increasing Cross-Institution Collaboration
- Redesigning Learning Spaces
- Rethinking How Institutions Work

Long-Term
Driving technology adoption in Chinese Higher Education for five or more years

- Advancing Cultures of Innovation
- The Rise of Coding as a Literacy
- Shift to Deep Learning Approaches

Significant Challenges Impeding Technology Adoption in Chinese Higher Education

Solvable
Those that we both understand and know how to solve

- Blending Formal and Nonformal Learning
- Improving Digital Literacy
- Integrating Technology in Teacher Education

Difficult
Those we understand but for which solutions are elusive

- Managing Big Data in Education
- Personalising Learning
- Scaling Teaching Innovations

Wicked
Those that are complex to even define, much less address

- Balancing Connected and Unconnected Life
- Rethinking the Roles of Educators
- Teaching Complex Thinking

Important Developments in Educational Technology for Chinese Higher Education

2017 2018 2019 2020 2021

Time-to-Adoption Horizon: One Year or Less

- Flipped Classroom
- Makerspaces
- Massive Open Online Courses (MOOCs)
- Mobile Learning

Time-to-Adoption Horizon: Two to Three Years

- Augmented & Virtual Reality
- Learning Analytics & Adaptive Learning
- Quantified Self
- Virtual and Remote Laboratories

Time-to-Adoption Horizon: Four to Five Years

- Affective Computing
- Machine Learning
- Robotics
- Volumetric & Holographic Displays

NMC

Executive Summary 1

Introduction 2

Key Trends Accelerating Technology Adoption 6

Significant Challenges Impeding Technology Adoption 8

Important Developments in Educational Technology:

Time-to-Adoption Horizon: One Year or Less

- Flipped Classroom 10
- Makerspaces 11
- Massive Open Online Courses (MOOCs) 12
- Mobile Learning 13

Time-to-Adoption Horizon: Two to Three Years

- Augmented & Virtual Reality 14
- Learning Analytics & Adaptive Learning 15
- Quantified Self 16
- Virtual and Remote Laboratories 17

Time-to-Adoption Horizon: Four to Five Years

- Affective Computing 18
- Machine Learning 19
- Robotics 20
- Volumetric and Holographic Displays 21

Methodology 22

2017 Horizon Project China Expert Panel 23

End Notes 24

2017 NMC Technology Outlook for Chinese Higher Education

A Horizon Project Regional Report

is a collaboration between

The New Media Consortium

and

Smart Learning Institute of Beijing Normal University

Citation

Adams Becker, S., Huang, R., Liu, D. J., Gao, Y., Cummins, M., Hall Giesinger, C., and Shedd, L. (2017). 2017 NMC Technology Outlook for Chinese Higher Education: A Horizon Project Regional Report. Austin, Texas: The New Media Consortium.

Cover image via BigStock Photography

978-0-9986242-0-4

Executive Summary

The *2017 NMC Technology Outlook for Chinese Higher Education: A Horizon Project Regional Report* reflects a collaborative research effort between the New Media Consortium (NMC) and the Smart Learning Institute of Beijing Normal University to inform Chinese university leaders and decision-makers about the significant developments in technologies supporting teaching, learning, and creative inquiry in higher education institutions across the country.

All of the research underpinning the report makes use of the NMC's Delphi-based process for bringing groups of experts to a consensus, in this case around the impact of emerging technologies on Chinese higher education over the next five years. The same process underlies the well-known *NMC Horizon Report* series, which is the most visible product of an on-going research effort begun more than 15 years ago to systematically identify and describe emerging technologies likely to have a large impact on education around the globe.

The *2017 NMC Technology Outlook for Chinese Higher Education* was produced to explore emerging developments in technology and forecast their potential impact expressly in a Chinese higher education context. In the effort that took place from July through September 2016, a selected panel of esteemed experts was asked to consider a host of relevant articles, news, blog posts, research, and project examples and ultimately pinpointed the most notable technology topics, trends, and challenges for Chinese universities over the next five years.

Known as the 2017 Horizon Project China Expert Panel, that group of thought leaders consists of knowledgeable individuals, all highly regarded in their fields. Collectively, the panel represents a range of diverse perspectives across the higher education sector. The project has been conducted under an open data philosophy, and all the interim products, secondary research, discussions, and ranking instrumentation can be viewed at china.nmc.org. The precise research methodology employed in producing the report is detailed in a special section found at the end of this report.

Nine key trends, nine significant challenges, and twelve important developments in technology were identified by the expert panel. The trends and challenges are intended to frame technology adoption in terms of the positive paradigm shifts advancing it and the obstacles impeding it. These influential discussions acknowledge that technology by itself is not a sufficient solution but instead an enabler of more effective teaching and learning approaches. Technology use must be grounded in progressive pedagogies and models that foster greater student engagement and performance. Both the trends and the challenges are placed into horizons; the trends range from long- to short-term while the challenges are classified by scope of difficulty.

Each of the twelve developments in technology is profiled on a single page that describes the topic and categorises it as very important for Chinese universities over the next year, two to three years, or four to five years. Every page opens with a carefully crafted definition of the highlighted development, outlines its educational relevance, points to several real-life examples of its current use, and ends with a short list of additional readings for those who wish to learn more.

Taken together, the three key sections of this report constitute a reference and straightforward technology planning guide for educators, university leaders, administrators, policymakers, and technologists. It is our hope that this research will inform the choices that institutions are making about technology to improve, support, or extend teaching, learning, and creative inquiry in China. Education stakeholders worldwide look to the NMC Horizon Project and both its global and regional reports as key strategic technology planning references, and it is for that purpose that the *2017 NMC Technology Outlook for Chinese Higher Education* is presented.

Introduction

What is on the five-year horizon of technology adoption for Chinese universities? Which trends and technology developments will drive real transformation in higher education? What are the critical challenges for which solutions are needed? These questions regarding technology adoption and educational change steered the discussions of a body of 85 experts to produce the *2017 NMC Technology Outlook for Chinese Higher Education*.

Nine key trends, nine significant challenges, and twelve developments in educational technology profiled in this report are poised to impact Chinese higher education. The topics converge in ways that tell a larger story about the state of teaching and learning across the country. These top five highlights capture the big picture themes of educational change that are unique to China and underpin the 30 topics:

1. Driving innovation is a top responsibility of Chinese universities. The growth of the national economy relies on the progressive ideas that stem from faculty, researchers, and students in higher education. As such, institutions must be structured in ways that promote the exchange of fresh ideas and embrace evidence-based approaches to technology deployment.

2. Real-world skills are needed to deepen learning outcomes, better preparing students for the workforce. The advent of makerspaces, classroom configurations that enable active learning, and the inclusion of coding and robotics are providing students with ample opportunities to create, iterate, and experiment in ways that spur complex thinking.

3. There is a gap between technology and pedagogy. As Chinese universities become more adept at integrating digital tools and resources into learning experiences, there is a need to develop strategies that align technology use with student-centred teaching approaches that promote deeper learning. Educators require ongoing professional development and support.

4. Artificial intelligence is driving greater personalisation and efficiency. The report's inclusion of adaptive learning, affective computing, and machine learning emphasises more sophisticated human-computer relationships. Algorithms that adapt as students learn have potential for providing more individualised attention and interventions in online environments.

5. Online, mobile, and blended learning are foregone conclusions. With China as a world leader in both mobile technology and internet usage, universities that do not already have robust strategies for connecting these tools and approaches to teaching and learning activities will not remain relevant. The exploration of massive open online courses (MOOCs) and open educational resources (OER) points to steps toward greater openness and inclusion.

The work of the 2017 Horizon Project China Expert Panel acknowledges that technology adoption in institutions across the country can be accelerated by the recognition of these themes — but also hampered by their complexity. It is important to look beyond the unique context of Chinese higher education to view how technology-driven trends and challenges are impacting the rest of the world. As such, the top three most highly ranked trends and challenges from three reports are included in the related tables in this summary, and are organised by categories described in the next sections of this report.

The tables illustrate the choices of the Chinese experts compared with those who contributed to the *NMC Horizon Report > 2017 Higher Education Edition,* which looked at technology uptake from a global perspective, and the *2016 NMC Technology Outlook for Australian Tertiary Education* with perspectives on technology impact in Australian universities — an appropriate benchmark for progress in China. Altogether, the three reports encompass a group of 210 acknowledged experts, with 85 Chinese experts, 79, global experts, and 46 Australian experts.

Table 1: Top-Ranked Trends Across Three NMC Horizon Research Projects

NMC Horizon Report 2017 Higher Education Edition	2017 Technology Outlook Chinese Higher Education	2016 Technology Outlook Australian Tertiary Education
Long-Term Trend		
Deeper Learning Approaches	Advancing Cultures of Innovation	Rise of More Authentic Assessment
Mid-Term Trend		
Redesigning Learning Spaces	Redesigning Learning Spaces	Redesigning Learning Spaces
Short-Term Trend		
Blended Learning Designs	Blended Learning Designs	Blended Learning Designs

As shown in Table 1, the top priorities of the Chinese panel align almost identically with both the global and Australian panels. Chinese higher education leaders are focused on systemically spurring creativity and invention, while configuring classroom layouts that are conducive to more active and authentic learning. The University of Nottingham Ningbo China's Incubator Centre combines all of these values; its open design fosters a sense of community and a seamless exchange of ideas. The space also connects students and staff to local start-ups, investors, and government representatives through programs and special events.[1]

Additionally, blended learning was identified as a top trend for China, a concept embraced by the other panels as well. Its short-term horizon placement indicates that new developments in this area are taking hold — often documented informally at institutions or not publicised. The Open University of China exemplifies the trend of blended learning through the deployment of their cloud classroom system, which combines physical classrooms with a virtual environment that is brimming with videos, learning resources, and opportunities for student-educator interactions.

The 2017 Chinese experts also agree that technology adoption is often hindered by both local and systemic challenges that make it difficult to discover and implement new tools and approaches. In some cases, there is not yet a consensus around the definition of a challenge itself, which makes envisioning solutions more ambiguous. Therefore, the NMC Horizon Project hopes to generate a shared understanding. In other cases, there may not be specific government policies or directives — or solutions may exist but institutional leaders have not yet determined how to scale them.

Table 2: Top-Ranked Challenges Across Three NMC Horizon Research Projects

NMC Horizon Report 2017 Higher Education Edition	2017 Technology Outlook Chinese Higher Education	2016 Technology Outlook Australian Tertiary Education
Solvable Challenge		
Improving Digital Literacy	Integrating Technology in Teacher Education	Creating Authentic Learning Opportunities
Difficult Challenge		
Advancing Digital Equity	Personalising Learning	Under-resourced Campus Infrastructure
Wicked Challenge		
Rethinking the Roles of Educators	Teaching Complex Thinking	Balancing Connected and Unconnected Life

As noted in Table 2, the choices of the 2017 Chinese panel are unique; however, the other two panels did consider them to be significant challenges as well — just not as highly ranked. Integrating technology in teacher education is perceived as solvable. Beijing Normal University is committed to reflecting on the approaches implemented in their education courses, particularly as they pilot micro-lessons that combine blended learning with individual and group work. They evaluate the outcomes of new models to devise effective strategy for pedagogy design.

The experts view personalising learning as a difficult challenge that is well understood but for which solutions are elusive. While more Chinese universities are leveraging learning analytics and adaptive learning to inform improved curriculum design and offer students individualised attention, these technologies have yet to be scaled. The University of Electronic Science and Technology of China is one notable solution; their digital Student Portrait System analyses the student behaviour to predict their possible development directions, prompting educators to provide personalised guidance.

In the realm of wicked challenges, the panel believes teaching complex thinking is the thorniest issue. The definition of complex thinking is nebulous, especially because traditional pedagogy and curriculum, as well as assessment-focused practice, are still commonplace at local institutions. Learning programming is perceived as a strategy for cultivating complex thinking as it combines computer science skills with creativity and critical thinking. In this respect, China is already surpassing other countries including the US and India by integrating coding into curricula as early as preschool.[2]

Fuelled by the key trends and impeded by significant challenges selected by the panel, the 12 important developments in technology presented in the body of this report reflect our experts' opinions as to which of the nearly 50 technology developments considered will be most important to Chinese higher education over the five years following the publication of the report.

Table 3: Comparison of "Final 12" Topics Across Three NMC Horizon Research Projects

NMC Horizon Report 2017 Higher Education Edition	2017 Technology Outlook Chinese Higher Education	2016 Technology Outlook Australian Tertiary Education
Time-to-Adoption Horizon: One Year or Less		
Adaptive Learning Technologies Big Data Makerspaces Mobile Learning	Flipped Classroom Makerspaces Massive Open Online Courses Mobile Learning	Bring Your Own Device Flipped Classroom Learning Analytics Online Learning
Time-to-Adoption Horizon: Two to Three Years		
Internet of Things Mixed Reality Next-Generation LMS Wearable Technology	Augmented & Virtual Reality Learning Analytics & Adaptive Learning Quantified Self Virtual & Remote Laboratories	Adaptive Learning Technologies Location Intelligence Makerspaces Wearable Technology
Time-to-Adoption Horizon: Four to Five Years		
Affective Computing Artificial Intelligence Natural User Interfaces Virtual Assistants	Affective Computing Machine Learning Robotics Volumetric & Holographic Displays	Affective Computing Augmented Reality Internet of Things Machine Learning

As reflected in the choices above, Chinese institutions are aligned with both global and Australian universities in terms of integrating many emerging technologies. Chinese experts viewed augmented and virtual reality (AR & VR) as about three years away from mainstream adoption, transporting learners to environments they may otherwise never be able to access. The University of Hong Kong is a leader in this area with their imseCAVE— an interactive visualisation system

that uses motion capture and VR to provide an enhanced view of complex engineering systems and operations.[3]
The inclusion of volumetric & holographic displays represents a divergent choice by the Chinese expert panel. With similar goals as applications of AR & VR, volumetric & holographic displays are part of a category of developments that leverage 3D technology to generate more immersive learning experience. For example, Advanced Theranostics and 3D Imaging Laboratory's Integral Videography at the Tsinghua University School of Medicine enables surgeons to view 3D autostereoscopic images containing anatomical information without special glasses.[4]

Also among the selections unique to the Chinese panel's selection were virtual and remote laboratories — enabling students to continuously run experiments wherever they are — as well as robotics, which have elevated in sophistication thanks to innovations stemming from universities across the country. Robotics is one example of a technology that is not only being increasingly leveraged in Chinese institutions, but created there as well. For example, China University of Political Science and Law and the University of New Haven launched China-US Forensic Technology Research Centre with the goal of developing robots that can scour crime scenes and provide police investigators with pertinent data that is otherwise difficult to pinpoint.[5]

Additionally, MOOCs and quantified self were all distinctly surfaced by the Chinese panel. The inclusion of MOOCs signifies the embracing of open education — a trend prominently demonstrated by the MOOC China Alliance, which was established by 37 local universities to develop high-quality, personalised learning experiences.[6] Meanwhile, the presence of quantified self in this report is the product of a growing interest in gathering and analysing data for learning, which can enable greater personalisation in Chinese higher education. Quantified devices can not only track learning performance but also underlying emotional responses that impact learning. Researchers at Chinese University of Hong Kong have set a precedent for this trend, using wearable devices with sensors to measure anxiety levels.[7]

The above developments reflect Chinese institutions' significant focus on advancing virtual and online arenas across the country. In an increasing number of scenarios, MOOCs, AR and VR, virtual and remote laboratories, and other emerging technologies are being used in tandem to create more engaging and data-driven learning experiences for students. These points and comparisons provide an important context for the main body of the report that follows.

Key Trends Accelerating Technology Adoption

The technology developments featured in the NMC Horizon Project are embedded within a contemporary context that reflects the realities of the time, both in the sphere of education and in the world at large. To assure this perspective, each panel member has researched, identified, and ranked key trends that are currently affecting teaching, learning, and creative inquiry in Chinese higher education, and used these as a lens for the work of predicting the uptake of emerging technologies. These nine trends, which the panel agreed are very likely to drive technology planning and decision-making over the next five years, are sorted into three time-related categories: short-term trends that will last for the next one to two years and are bound to become pervasive in institutions, and two categories of slower trends that are growing more incrementally.

Short-Term Trends

Driving technology adoption in Chinese Higher Education over the next one to two years

Increasing Use of Blended Learning Designs. Drawing from best practices in both online and face-to-face methods, blended learning is on the rise at Chinese universities. Training and supporting faculty in integrating digital resources and implementing new processes is key in the success of blended approaches. Inner Mongolia University for the Nationalities has addressed this notion by establishing a reform institute to conduct multi-level training on using blended resources, along with a quality control mechanism and an incentive and support system.[8]

Proliferation of Open Educational Resources. Defined by the Hewlett Foundation, open educational resources (OER) are “teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use and re-purposing by others.”[9] Chinese universities are taking advantage of each other’s expertise by sharing specialised courses and content, especially in a manner that allows for re-mixing and personalisation. The Open University of China is leading the way with its Open University Cloud Classroom that caters to both face-to-face or virtual settings; the platform hosts live and recorded broadcasting, dynamic real-time interaction and feedback, multi-terminal access, and large-scale distributed network interaction.

Rise of STEAM Learning. There has been a growing global emphasis on developing stronger science, technology, engineering, and mathematics (STEM) curriculum and programmes, as these disciplines are widely viewed as the means to boost innovation and bolster national economies. While China is the world's leading producer of undergraduates with degrees in science and engineering,[10] the Chinese Premier Li Keqiang has recently called on the country's institutions to better coordinate with each other in their science and technology research.[11] The STEAM learning movement, in which the A stands for “art+,” is based on the notion that a more balanced curriculum that integrates disciplines such as the arts, design, and humanities into the sciences encourages more intellectual curiosity and creative thinking. Hong Kong has recently reformed the curriculum across eight local universities, adding an additional year of liberal arts subjects.[12]

Mid-Term Trends

Driving technology adoption in Chinese Higher Education over the next three to five years

Increasing Cross-Institution Collaboration. Today’s global environment is allowing universities to unite across international borders and work toward common goals concerning technology, research, or shared values. As institutions leverage IT to help transcend geographical, institutional, and cultural boundaries, consortia like the iPodia Alliance are being formed to establish common technical and infrastructural standards and allow online learning resources to be networked internationally across campuses to form cross-cultural environments.[13] Another example, C-

Campus, is an online cloud-based platform that facilitates joint projects, research, and knowledge exchanges between KTH Campus in Stockholm and Tsinghua University in Beijing.[14]

Redesigning Learning Spaces. As universities incorporate digital elements and accommodate more active learning, they are rearranging physical environments to enable pedagogical shifts that facilitate organic interactions and cross-disciplinary work. Chinese educational settings are increasingly being designed to resemble real-world work and social environments that support project-based interactions with attention to expanded mobility, flexibility, and device usage. Beijing Normal University has created new pilot classrooms with features including configurable furniture, recording and multimedia tools, and large displays and software that enable remote communication and collaboration with international partners. They are also leveraging surveys, interviews, and classroom observations for faculty and student feedback on the investments.[15]

Rethinking How Institutions Work. There is a focused movement to reinvent the traditional classroom paradigm and rearrange the entire formal education experience — a trend that is largely being driven by the influence of innovative learning approaches. Methods such as project- and challenge-based learning call for structures that enable students to move from one learning activity to another more organically, removing the limitations of seemingly disparate disciplines. Made in China 2025, along with the 13th Five Year Plan, Internet Plus, and Belt & Road Initiative are driving institutions to better accommodate cross-disciplinary and collaborative learning and produce critical thinkers and makers who thrive in China's evolving economy.[16]

Long-Term Trends

Driving technology adoption in Chinese Higher Education for five or more years

Advancing Cultures of Innovation. As campuses have evolved into hotbeds for entrepreneurship and discovery, higher education has become a vehicle for driving innovation. *China Education Daily* reports that 82% of universities have created innovation and entrepreneurship courses. Tsinghua University has adjusted its curriculum to include several cross-disciplinary minors, from future robotics to smart transportation.[17] A number of Chinese universities are also establishing group innovation spaces — a term that encompasses makerspaces that encourage experimentation and incubators that help bring research findings from lab to market. Examples of these services include Fudan University's Science Park, Tsinghua University's iCenter and x-lab, and Peking University's Entrepreneur's Training Camp.[18]

The Rise of Coding as a Literacy. Coding refers to a set of rules that computers understand and can take the form of numerous languages, such as HTML, JavaScript, and PHP. Many educators perceive coding as a way to stimulate computational thinking: the skills required to learn coding combine deep computer science knowledge with creativity and problem-solving. Jobs employing coding — specifically, game designers, internet developers, and software engineers — have recently been rated as the top three highest-paying positions in China,[19] and an increasing number of Chinese education start-ups are catering to the demand for these skills by offering coding, IT training services, and boot camps that immerse students in projects that provide them with practical experience and finished products to showcase to prospective employers.[20] [21]

Shift to Deep Learning Approaches. There is an ongoing emphasis in higher education on deeper learning approaches, defined as the mastery of content that engages students in critical thinking, problem-solving, collaborating, and self-directed learning. With a rising level of unemployment among new graduates in China,[22] students need to be able to make clear connections between their coursework and the real world. Through the Guangdong Technical and Vocational Education and Training Project, the country is exploring ways to reform its job-specific training system by embracing competency-based skills development, active learning, and proficiency in practical skills instead of performance assessments based on exam results alone.[23]

Significant Challenges Impeding Technology Adoption

Along with the trends discussed in the preceding section, the expert panel noted a number of significant challenges faced in Chinese higher education that are impeding the uptake of emerging technologies. Because not all challenges are of the same scope, the discussions here are sorted into three categories defined by the nature of the challenge. The NMC Horizon Project defines solvable challenges as those that we both understand and know how to solve; difficult challenges are ones that are more or less well understood, but for which solutions remain elusive. Wicked challenges, the most difficult, are categorised as complex to even define, and thus require additional data and insights before solutions will be possible.

Solvable Challenges

Those that we both understand and know how to solve

Blending Formal and Nonformal Learning. As the internet fosters the ability to learn about almost anything, there is increasing interest in self-directed and curiosity-based learning. These, along with life experience and other serendipitous forms of learning, fall under the banner of nonformal learning, inspiring people to follow their own learning pathways. This challenge is considered solvable as open learning through the "self-study examination" has thrived in China,[24] with independent studies encouraged at institutions including Southwest Jiaotong University.[25] Encouraging students to pursue their passions and curiosities outside of mandated curriculum (and even as they participate in the workforce) is essential for integrating nonformal opportunities.

Improving Digital Literacy. The productive and innovative use of technology encompasses 21st century practices that are vital for success in the workplace and beyond.[26] Digital literacy transcends gaining isolated technological skills to generating a deeper understanding of the digital environment, enabling intuitive adaptation to new contexts and co-creation of content with others.[27] Chinese institutions are charged with developing students' digital citizenship, ensuring mastery of responsible technology use, including online communication etiquette in blended and online learning settings.[28] In China, more educators are leveraging the popularity of social network WeChat to facilitate student discussions and review assignments.[29] However, this challenge is still affecting curriculum design, professional development, and student services. Due to the complexity of digital literacy, higher education leaders struggle to obtain institution-wide buy-in and to support all stakeholders in developing these competencies.

Integrating Technology in Teacher Education. In the past 20 years, many Chinese ministers of education have issued national agendas that emphasise the importance of modernising education through the use of emerging technologies.[30] However, despite agreement on the importance of digital competence, training in digitally-supported teaching methods is not common enough. Teachers require extensive exposure to technology to be able to evaluate and choose the most appropriate tools. Beijing Normal University (BNU) recognises that when implementing new technology-enabled activities for learners, there is an opportunity to reflect on the teaching practices employed. In education courses, they have adopted a blended micro-lesson approach where students who are training to be teachers engage in lesson preparation, lesson teaching, and creating video reflections. This approach has informed BNU's strategy for pedagogy design.

Difficult Challenges

Those we understand but for which solutions are elusive

Managing Big Data in Education. Today, many interactions made over the internet are being tracked, stored, and used in targeted ways. This has led to the notion of big data — massive amounts of data that reflect the behaviour and actions of various populations. Data scientists and data collection platforms are now able to computationally organise this information to analyse

and easily identify patterns that may have otherwise gone undetected. In academia, data on student performance as well as on the pockets of innovation stemming from universities is of growing interest. The expert panel, however, believes that data management policies and regulation in higher education must be improved. At the national level, educational data is as secure as financial data; there needs to be more open dialogue and accessible pathways to interpreting it to inform smarter education agendas and promote greater innovation.[31]

Personalising Learning. Personalised learning refers to the range of educational programmes, learning experiences, instructional approaches, and academic support strategies intended to address the specific learning needs, interests, aspirations, or backgrounds of individual students.[32] While there is demand for personalised learning, it is not adequately supported by current technology or practices in Chinese universities at scale. Advancements in online and adaptive learning are making it more possible to support individual learning paths. At the University of Electronic Science and Technology of China, the digital Student Portrait System analyses the real-time behaviour data obtained from students' daily learning activities to predict their possible development directions, making it easier for educators to provide more personalised guidance.

Scaling Teaching Innovations. Chinese institutions are not yet adept at moving teaching innovations into mainstream practice. Innovation springs from the freedom to connect ideas in new ways. Universities generally allow educators and students to connect ideas only in prescribed ways — sometimes these lead to new insights, but more likely they lead to rote learning. Current organisational promotion structures rarely reward innovation and improvements in teaching and learning. A pervasive aversion to change limits the diffusion of new ideas, and too often discourages experimentation.

Wicked Challenges

Those that are complex to even define, much less address

Balancing Connected and Unconnected Life. In 2016, research on global technology usage identified China as the world leader in mobile technology, especially with 800 million monthly active users on the WeChat app.[33] With technology now at the centre of daily life, institutions must help learners understand how to balance their usage with other developmental needs. To prevent students from getting lost in the abundant sea of new media, Chinese universities should encourage mindful use of digital tools while making them aware of their digital footprint and the accompanying implications. As education aligns more closely with technological trends, educators should promote this balance, facilitating opportunities where students feel, digest, reflect, touch, and pursue sensorial experiences that are crucial to developing character and integrity.

Rethinking the Roles of Educators. Educators are increasingly tasked with leveraging active learning methodologies like project- and problem-based learning. This shift to student-centred learning requires them to act as guides and facilitators.[34] As these technology-enabled approaches gather momentum, institutions are rethinking educators’ responsibilities. The Chinese ministry of education has promoted entrepreneurial learning, driving students to generate new ideas and products that bolster the national economy. Tsinghua University has long been a model for these efforts with their business competitions.[35] In these scenarios, educators must be able to help individuals and teams of students bring their business plans to fruition.

Teaching Complex Thinking. It is essential for learners both to understand the networked world and to deploy heuristic reasoning to address the pressing problems around them. Unfortunately, many Chinese institutions still emphasise traditional curricula and assessments that do not factor in creative and critical thinking. Teaching coding is increasingly being viewed as a way to instil this kind of thinking in students. China is rising to this challenge by incorporating coding lessons into formal education, setting up students on a long-term path to developing advanced skills.[36]

Time-to-Adoption: One Year or Less

Flipped Classroom

The flipped classroom refers to a model of learning that rearranges how time is spent both in and out of class to shift the ownership of learning from the educators to the students.[37] In the flipped classroom model, valuable class time is devoted to higher cognitive, more active, project-based learning where students work together to solve local or global challenges — or other real-world applications — to gain a deeper understanding of the subject.[38] Rather than the instructor using class time to dispense information, that work is done by each student after class, and can take the form of watching video lectures, listening to podcasts, perusing enhanced e-book content, or collaborating with peers in online communities.[39] Students access the online tools and resources any time they need them. Faculty can then devote more time to interacting with each individual. After class, students manage the content they use, the pace and style of learning, and the ways in which they demonstrate their knowledge; the instructor adapts instructional and collaborative approaches to suit their learning needs and personal learning journeys.[40] Launched in June 2016, the Flipped Learning Global Initiative (FLGI) aims to support flipped classroom integration around the globe. FLGI's Research Fellows are researchers and flipped classroom practitioners from variety of institutions, including Shaanxi Normal University's Dr. BaoHui Zhang.[41]

Relevance for Teaching, Learning, or Creative Inquiry

- Flipped classroom concepts, as well as providing students with a more diverse set of learning resources, can support self-directed learning.
- More active learning is an important component of the flipped classroom: lectures can be watched with ensuing online discussions unfolding at home, while instructors can use class time for hands-on activities or trips outside of the building.
- The online component of the flipped classroom enables students to repeat vital learning activities, such as re-watching video lectures and running virtual experiments as often as needed, in order for them to fully grasp the subject matter.

Flipped Classroom in Practice

- An English class at Liaoning Police Academy, Dalian, China incorporated flipped classroom techniques with micro-course elements designed in explicitly layered teaching for students at different performance levels: go.nmc.org/emotkin. (PDF)
- At Hohai University's School of Foreign Languages, a flipped classroom in a Business English writing class that is using Clickers to encourage student engagement demonstrated greater learning and student satisfaction than a traditional class taught by the same professor: go.nmc.org/achiev. (PDF)
- Xi'an Jiaotong-Liverpool University opened the Digital Learning Resources Hub, a media lab designed to support video production, especially in support of the flipped classroom instructional model: go.nmc.org/flipcont.

For Further Reading

Breaking Through the Biggest Barrier to Flipped Learning
go.nmc.org/breakthr

(Jon Bergmann Atasi Mohanty, *Flipped Learning*, 6 July 2016.) This article explores design considerations for creating a computational agent capable of measuring and responding to student emotions during the learning process to increase engagement and motivation in flipped classroom environments.

Seamless Flipped Learning
go.nmc.org/seaml

(Gwo-Jen Hwang and Chiu-Lin LaiSiang-Yi Wang, Journal of Computers in Education, 15 August 2015.) The authors argue that the culmination of the flipped classroom model and mobile technologies create the opportunity for what they call "seamless flipped learning."

Time-to-Adoption: One Year or Less

Makerspaces

The turn of the 21st century has signalled a shift in what types of skillsets have real, applicable value in a rapidly advancing world. The question of how to renovate or repurpose learning environments to address the needs of the future is being answered through the concept of makerspaces, or workshops that offer tools and the learning experiences needed to help carry out ideas.[42] Makerspaces are intended to appeal to people of all ages, and are founded on openness to experiment, iterate, and create. In this landscape, creativity, design, and engineering are at the forefront of educational considerations, as tools such as 3D printers, robotics, and web-based 3D modelling applications become more accessible. The Chinese word "chuangke" derives from the English word "maker," and refers to people who create and design new things.[43] In China, an increasing number of community makerspaces are populating major cities and mass production hubs, spurring innovation and entrepreneurship alongside other government initiatives such as Internet Plus.[44] Thought leaders believe that makerspaces are fostering significant innovation across the country because they promote open communities and exchanges of ideas.[45]

Relevance for Teaching, Learning, or Creative Inquiry

- Makerspaces equipped with technologies and construction supplies are all-purpose workshops that represent the power of creation in both the virtual and physical world.
- Makerspaces that can be accessed outside of scheduled classes provide a place for faculty and students to pursue making activities on their own, which promote design skills.
- Pedagogies such as inquiry-based learning and design thinking, which encourage construction and higher-order thinking, can be carried out in makerspaces, leading to greater economic development.

Makerspaces in Practice

- Beijing University of Posts and Telecommunications created the Maker Toolbox, which helps integrate maker education courses into compulsory curricula and blended maker environments to advance students' knowledge of software, computer system structure, digital circuitry, analog electronics, and information networks: go.nmc.org/bupt.
- Students cultivate entrepreneurial skills at Tsinghua University's i.Center, transforming vision into reality by using laser cutters, milling machines, and 3D printers and scanners: go.nmc.org/icen.
- Through its Incubator Centre, the University of Nottingham Ningbo China has established a site for students, staff, and community members to create and exchange ideas. The open design fosters collaborating and co-working to promote innovation: go.nmc.org/unnc.

For Further Reading

Hacking with Chinese Characteristics
go.nmc.org/hackw

(Silvia Lindtner, *Science, Technology, & Human Values*, July 2015.) A researcher describes why China's maker culture is unique due to its roots in Shanzhai, which reflects an open ecosystem of component producers, design solution houses, vendors, and assembly lines.

Maker Movement, a New Industrial Revolution
go.nmc.org/newind

(CCTV.com, 6 June 2016.) This article details the role of makerspaces in China's larger societal shifts, empowering individuals to start businesses, invent products, and transform ideas into reality.

Time-to-Adoption: One Year or Less

Massive Open Online Courses (MOOCs)

When the term was coined in 2008, massive open online courses (MOOCs) were conceptualised as the next evolution of networked learning. The essence of the original MOOC concept was a web course developed using open source content that people could take from anywhere across the world.[46] Since then, MOOCs have grown exponentially in number and international reach, but challenges remain to be resolved in engaging learners at scale and providing authentic knowledge transfer along with respected credentials. In the past decade, various Chinese government policies have supported and encouraged the development and sharing of high quality educational resources along with the digitisation of courses.[47] The Chinese Ministry of Education has set a target for Chinese higher education institutions to develop 1,000 MOOCs by 2017 and 3,000 by 2020.[48] Partnerships with local industries are helping universities develop courses that prepare students for in-demand career fields, while cross-institutional collaboration, both locally and worldwide, exposes Chinese students to more variety in learning content and educator talent. For example, National University of Defense Technology created the Mengke Platform to provide brief video lectures from 24 universities and armies to help train soldiers.

Relevance for Teaching, Learning, or Creative Inquiry

- Educators are leveraging data from MOOCs to refine their courses both on- and offline, based on student engagement and feedback.[49]
- MOOCs are encouraging the development, access, and improvement of high-quality open educational resources.
- There is potential for MOOCs to play a role in helping China address inequality in educational access for rural, low-income, disabled, and other underserved populations.[50]

MOOCs in Practice

- The MOOC China Alliance was established by 37 local universities to help the government and society realise collective goals; they aim to develop high-quality MOOCs that deliver personalised experiences: go.nmc.org/mchina.
- Researchers analysed a dataset from xuetangX, one of China's largest MOOCs, to better understand the factors likely to lead to student engagement or attrition: go.nmc.org/modelpred. (PDF)
- Shanghai Jiao Tong University has partnered with IBM to offer big data analytics courses and a Chinese version of IBM's Data Scientist Workbench platform of open source tools on their free MOOC platform, CNMOOC: go.nmc.org/turntech.

For Further Reading

MOOCs: Vital Tools in Education of the Future - or Over-Hyped Online Fad
go.nmc.org/vitaltoo

(Sarah Chappell, *Euronews*, 3 April 2016.) MOOC providers have found that leveraging crowdsourcing for translations and content corrections alleviates language and government barriers that previously limited learning opportunities for Chinese students.

Motivation Classification and Grade Prediction for MOOCs Learners
go.nmc.org/motclass

(Bin Xu and Dan Yang, *Computational Intelligence and Neuroscience*, 2016.) Chinese researchers are studying how the detailed activity records of learners provided by MOOCs can aid educators in predicting learner behaviour and intervening or providing support.

Time-to-Adoption: One Year or Less

Mobile Learning

Learning happens all-the-time, everywhere, and is not place-bound.[51] With the proliferation of personal mobile devices, people increasingly expect to be connected to the internet and the rich tapestry of knowledge it contains wherever they go. According to the China Internet Network Information Center, at the end of 2016 the number of Chinese people using the internet had reached 731 million (half the country's population), with 95.1% of them accessing the web through their smartphones.[52] Currently China's Ministry of Education is challenged with finding solutions to lessen the disparity between urban and rural China, and mobile delivery is one method of reaching more low income citizens who might not have a computer at home, but will likely have a smartphone.[53] Mobile devices can break down institutional walls by extending the availability and accessibility of learning content and expertise, while allowing learners more flexibility and variety in how they share knowledge and collaborate. Chinese education researchers are finding that the effective use of mobiles can support learning across multiple environments,[54] while facilitating a shift from passive learning to more autonomous learning, where students actively seek out resources based on their personal interests.[55]

Relevance for Teaching, Learning, or Creative Inquiry

- Mobile apps with built-in social features enable learners to share questions or collaborate on creative projects instantaneously.
- Mobiles present an economic, flexible alternative to laptops and desktops due to the devices' lower cost, greater portability, and access to apps.
- Personal mobile devices can provide an entry point to customised learning content and the ability to generate data on related interactions.

Mobile Learning in Practice

- Nantong University offered a two-week mobile learning course on Photographic Technique using WeChat to encourage student discussion and problem-solving.
- "Rain Classroom" is a free mobile data collecting system that integrates with the WeChat and PowerPoint apps to track student learning outcomes and behaviours: go.nmc.org/ykt.
- A researcher at Jiujiang University tested his mobile app aimed at helping Chinese students to better retain English vocabulary and reported a significant improvement in the vocabulary of students using the app versus those who did not: go.nmc.org/pullmobile.
- Xi'an Eurasia University's Tronclass education platform pushes reminders and notifications of upcoming work and class deadlines to students; it also integrates with their Smart Campus Platform to provide university-wide news and safety alerts: go.nmc.org/eura.

For Further Reading

Connected Learning: How Mobile Technology Can Improve Education (PDF)
go.nmc.org/canimp

(Darrell M. West, Brookings Institution, December 2015.) Mobile devices offer students access to educational digital content including games, augmented reality, and social apps in a customised manner that can even provide real-time assessment and feedback.

GPS Sensor-Based Mobile Learning for English
go.nmc.org/gpsen

(Jerry Chih-Yuan Sun, et al., Springer Open, 17 November 2015.) This study explores how GPS sensor-based smartphone apps can enable contextually-aware learning experiences as students apply concepts they are learning to the world around them.

Time-to-Adoption: Two to Three Years

Augmented & Virtual Reality

Augmented reality (AR), the layering of data over 3D spaces to produce a new experience of the world, sometimes referred to as "blended reality," amplifies access to information, bringing new opportunities for learning. Virtual reality (VR) describes computer-generated environments that simulate the physical presence of people and objects to generate realistic sensory experiences. Both AR and VR are becoming increasingly viable in the education sector. VR constructs provide contextual learning experiences that foster exploration of real-world data in virtual surroundings,[56] while AR's responsive interactivity enables students to establish broader understandings based on interactions with virtual objects. These two immersive technologies foster deeper levels of cognition as learners attain new perspectives on underlying data. China is an ideal market for AR and VR development, with the world's highest penetration rate for smartphones. Recent government support for the integration of internet technologies will help this development gain traction, including the Internet Plus action plan and China's first large data exchange.[57] China's VR market is expected to reach ¥55 billion in value by 2020.[58] Meanwhile, Chinese universities are building innovation centres and alliances that encourage faculty and student experimentation with AR and VR technologies while connecting them with relevant industries.[59]

Relevance for Teaching, Learning, or Creative Inquiry

- AR can help students learn by placing course content in rich contextual settings that more closely mirror real-world situations.
- Both AR and VR can extend the walls of lecture halls, allowing students to explore and interact with environments and other people that may otherwise be inaccessible.
- VR can help institutions overcome shortcomings, including a reliance on theory and lack of concrete experiences, through experiential learning using simulations.

Augmented & Virtual Reality in Practice

- The University of Hong Kong's imseCAVE is an interactive visualisation system leveraging motion capture and VR to provide cost-effective design, analysis, and evaluation of complex engineering systems and operations: go.nmc.org/humsys.
- Suzhou MXR Software Technology Co. uses AR for teaching medical anatomy. Through the 3D models, audio, and video, the application makes learning more interactive and exploratory: go.nmc.org/suz.
- Xi'an recently hosted Augmented Reality Innovation Contest 2016 to encourage local research, collaboration, and influence within the AR and VR industry: go.nmc.org/indus.

For Further Reading

Augmented Reality and Virtual Reality Go to Work
go.nmc.org/augvirt

(Nelson Kunkel, *Deloite University Press*, 24 February 2016.) Augmented reality and virtual reality have introduced new interfaces that are changing how organisations do business — improving fidelity of intention, increasing efficiency, and fostering innovation.

The Promise of Virtual Reality in Higher Education
go.nmc.org/promof

(Bryan Sinclair and Glenn Gunhouse, *EDUCAUSE Review*, 7 March 2016.) VR aspires to engage users in new experiences, such as journeying through the solar system or better understanding the experience of a refugee uprooted by war.

Time-to-Adoption: Two to Three Years

Learning Analytics & Adaptive Learning

Learning analytics is an educational application of web analytics aimed at learner profiling, a process of gathering and analysing details of individual student interactions in online learning activities. The goal is to build better pedagogies, empower active learning, target at-risk student populations, and assess factors affecting completion and student success.[60] For educators and researchers, learning analytics has been crucial to gaining insights about student interaction with online texts and courseware.[61] Adaptive learning technologies apply analytics through software and online platforms, adjusting to individual students' needs.[62] Contemporary educational tools are now capable of learning the way people learn. Enabled by machine learning, they can adapt to each student in real time. The Global Chinese Conference on Computers in Education 2016 included a Learning Analytics and Assessment track to help scale successful strategies for technology implementation.[63] Chinese universities are engaging in cross-institutional research collaborations to better understand the impact of these applications on learner outcomes.

Relevance for Teaching, Learning, or Creative Inquiry

- Adaptive learning technologies link specific concepts and skills from a course to how students are interacting with the material.
- Learning analytics and adaptive learning technologies can help surface early signals that indicate a student who is struggling, allowing faculty to address issues quickly.
- The science behind learning analytics in online environments can be used to create adaptive software that caters to a student's individual learning curve in real time.

Learning Analytics & Adaptive Learning in Practice

- PERFORM, a joint project of Beijing Normal University and Universidad Internacional de la Rioja, aims to develop software that harnesses learner data to provide personalised recommendations: go.nmc.org/unir.
- Researchers from Peking University (PKU) and the University of Minnesota have partnered to extract learning analytics data on teachers who engage in PKU's professional development MOOCs to generate user profiles, in order to scale the format and provide continuing education opportunities for teachers in developing countries: go.nmc.org/aretra.
- A team at East China Normal University has created a Learning Analytics Intervention Model (LAIM) to monitor and measure learner performance. The LAIM will help instructors provide targeted assistance to students as they progress through content in the Sakai adaptive learning platform: go.nmc.org/chinpers.

For Further Reading

Clearing the Hurdles to Adaptive Learning
go.nmc.org/clearing
(Barb Freda, *University Business*, 26 August 2016.) This article offers suggestions from solution developers and practitioners on adopting adaptive learning technologies, including developing methods to measure efficacy, helping staff and students implement new technologies, and utilising data generated by adaptive platforms.

The Colleges Are Watching
go.nmc.org/arewait
(Mikhail Zinshteyn, *The Atlantic*, 1 November 2016.) With unprecedented access to student data and sophisticated predictive analysis tools, education institutions balance issues of student privacy while fostering academic success.

Time-to-Adoption: Two to Three Years

Quantified Self

Quantified self describes the phenomenon of consumers being able to closely track data that is relevant to their everyday lives through the use of technology. The uptake in China of affordable wearable devices such as Xiaomi's Mi Band and Amazfit smart jewellery, designed to automatically collect data, is helping people manage their fitness, sleep cycles, and eating habits.[64] Mobile apps also share a central role in this idea by providing easy-to-read dashboards for consumers to view and analyse their personal metrics. Users of these tools for self-assessment are empowered by the data they collect, and learners can potentially benefit from passive monitoring of key data points such as the amount of time spent, location, and even a user's emotional state as they interact with learning content, each other, and the world around them. Combined with the increasingly predictive power of machine learning, these devices can further benefit wearers by providing notifications and personalised recommendations based on the wearer's aspirations to help them stay on track in reaching their goals.[65] A recent survey revealed that 45% of China's online population currently tracks their health and fitness using an app or a wearable device with the main reasons cited as motivation and self-improvement. Learners and educators could benefit from similar tools for accountability in tracking progress toward educational goals.[66]

Relevance for Teaching, Learning, or Creative Inquiry

- Analytic insights enabled by self-quantification techniques provide students with tools that encourage self-reflection and support autonomous, self-directed learning.
- Quantifying personal data can help bridge formal and informal learning by tracking a variety of daily learning experiences in and outside of the classroom and providing personalised insight to connect experiences to learning content.
- Quantified self technologies can facilitate more seamless data capture to assist faculty and students in their field work and research.[67]

Quantified Self in Practice

- Chinese University of Hong Kong researchers used wearable devices with sensors to measure psychological indicators related to the anxiety levels of wearers: go.nmc.org/unob.
- A global group of university practitioners and researchers recently organised a New Frontiers of Quantified Self Workshop to explore how personal data can enable personalised services: go.nmc.org/newfron. (PDF)
- Researchers from the Northeastern University in China have developed a wearable smart necklace that records the sounds as a wearer eats and matches them against a catalogue of sounds to identify and track food intake: go.nmc.org/autodiet.

For Further Reading

Wearables Momentum Continues
go.nmc.org/momentum
(CCS Insight, 17 February 2016.) CCS Insight forecasts 411 million smart wearables worth $34 billion will be sold in 2020; currently China is the world's biggest market for wearables, with devices in the quantified self segment being a major contributor.

Wearable Tech Weaves Its Way into Learning
go.nmc.org/weaves
(Marguerite McNeal, *EdSurge*, 17 November 2016.) Devices with eye trackers and other sensors can capture data such as heart rate, emotions, and engagement levels to inform evidence-based targeted teaching and learning support.

Time-to-Adoption: Two to Three Years

Virtual and Remote Laboratories

Virtual and remote laboratories reflect a movement among education institutions to make the equipment and elements of a physical science laboratory more easily available to learners from any location, via the web. Virtual laboratories are web applications that emulate the operation of real laboratories and enable students to practice in a "safe" environment before using real, physical components. Students can typically access virtual labs anytime and anywhere. Some emerging virtual lab platforms also incorporate reporting templates that populate with the results of the experiments so that students and instructors can easily review the outcomes.[68] Remote laboratories, on the other hand, provide a virtual interface to a real, physical laboratory. Institutions that do not have access to high-caliber lab equipment can run experiments and perform lab work online, where users are able to manipulate the equipment and watch the activities unfold via a webcam. This provides students with a realistic view of system behaviour and allows them to access professional laboratory tools from anywhere, whenever they need.[69] Additionally, remote labs alleviate some financial burden for institutions as they can forgo purchasing specific equipment and use the remote tools that are at their disposal.[70]

Relevance for Teaching, Learning, or Creative Inquiry

- Because virtual laboratories do not involve real equipment or chemicals, learners have opportunities to run experiments more than once to improve understanding.
- Instructors play back videos of the experiments students have run online, pinpoint areas for improvement or further discussion, and acknowledge students who have excelled.
- Virtual and remote laboratories increase access to science tools without exposing students to potentially dangerous materials and processes.

Virtual and Remote Laboratories in Practice

- Learners discover applied physics and practice data analysis through the Remote Lab at the Hong Kong Polytechnic University. Originally designed for pre-service teachers, the lab has expanded access to students: go.nmc.org/remlab.
- Researchers at the University of Hong Kong's Virtual Laboratory of Urban Environments & Human Health are using both virtual and physical urban settings to investigate the impact of green spaces and other environmental features on human well-being: go.nmc.org/urbanenv.
- South China University of Technology's Virtual Simulation Mechanical Engineering Experimental Teaching Centre provides a venue for experimentation, practicing product assembly, and software simulations: go.nmc.org/scut.

For Further Reading

The Virtual Lab Advantage in Higher Ed
go.nmc.org/labadv

(Kelly Walsh, *University Business*, 24 May 2016.) Virtual labs offer a pathway for online learners to experience course components in a flexible delivery format. Students can experience technical challenges as they access labs through a variety of devices and operating systems.

Virtual Simulations as Preparation for Lab Exercises
go.nmc.org/virtsim

(Guido Makransky et al., PLOS ONE, 2 June 2016.) Before a physical lab activity, students who completed a virtual lab exercise were equally prepared as students who witnessed a face-to-face demonstration. Each group displayed similar improvements in knowledge and learning motivation.

Time-to-Adoption: Four to Five Years

Affective Computing

Affective computing refers to the idea that humans can program machines to recognise, interpret, process, and simulate the range of human emotions.[71] This concept revolves around the development of computers attaining humanlike understanding through activities such as implementing a video camera to capture facial cues and gestures that work in conjunction with an algorithm that detects and interprets these interactions. Affective computing recognises emotional and behavioural signals that trigger a reactionary process. Field leaders from across the globe gathered in Xi'an, China in 2015 at the International Conference on Affective Computing and Intelligent Interaction to share the latest ideas on relating biological processes to the design of computing systems.[72] In Chinese higher education, affective computing holds the potential to enhance online learning situations wherein a computerised tutor reacts to facial indications of confusion or boredom from a student in an effort to motivate or boost confidence. As MOOCs gain prominence in China,[73] mapping student emotions can help instructors facilitate a personalised learning experience.[74] With researchers at work on educational applications, growth in the field of affective computing has deep implications for the future of human and computer interactions.

Relevance for Teaching, Learning, or Creative Inquiry

- As institutions harness analytics to assess students' knowledge, affective computing can fill in an elusive part of the picture by understanding learner attitudes and emotions.
- The move toward machines that understand social cues and imitate human behaviour reflects the 21st century societal prioritisation of emotional intelligence and empathy.
- When applied to robots, affective computing can help improve emerging teaching practices such as remote instruction through telepresence.

Affective Computing in Practice

- At Sichuan University, a professor has implemented facial recognition software to measure students' interest levels during lectures, informing future changes to his curriculum design: go.nmc.org/recogni.
- Researchers from several institutions found that eye-tracking sensors in online environments can accurately assess students' Chinese reading proficiency, allowing instructors to tailor content to aptitudes and diagnose learning disabilities: go.nmc.org/onsens.
- A study at the University of Chinese Academy of Sciences used the Microsoft Kinect sensor system to capture students' walking gait and successfully determined their emotional states through affective computing methods: go.nmc.org/kinmot. (PDF)

For Further Reading

Affective Computing: How 'Emotional Machines' Are About to Take Over Our Lives
go.nmc.org/takeover

(Madhumita Murgia, *The Telegraph*, 15 January 2016.) Context-aware, emotionally responsive devices are being deployed in the film, television, and advertising industries to measure human reactions. The growing field of affective computing also has potential to impact management of health and medical conditions such as autism and epilepsy.

Affective Pedagogical Agent in E-Learning Environment: A Reflective Analysis (PDF)
go.nmc.org/affagent

(Atasi Mohanty, *Creative Education*, 13 April 2016.) This article explores design considerations for creating a computational agent capable of measuring and responding to student emotions during the learning process to increase engagement and motivation.

Time-to-Adoption: Four to Five Years

Machine Learning

Machine learning refers to computers that can act and react without being explicitly programmed to do so.[75] Practical speech recognition, semantic applications, and even self-driving cars all leverage machine learning via data systems that not only intake, retrieve, and interpret data, but also to learn from it. To do this, the machine must make a generalisation using algorithms to respond to new inputs after being “trained” on a different learning data set — much like a human learns from experiences and uses that knowledge to respond appropriately in a different encounter. In this sense, machine learning is widely considered by many as a step towards humanlike artificial intelligence. Chinese developers have access to large volumes of valuable training data from their internet-user base of nearly 700 million; this combined with China’s expansive pool of talent in engineering and the high quality of research produced is driving advances in the field.[76] Chinese computer scientists are discovering machine learning’s potential benefit for society, for example, by calculating pollution forecasts that can inform government policies to mitigate health and climate effects of air pollution.[77]

Relevance for Teaching, Learning, or Creative Inquiry

- Machine learning is changing how researchers study the learning process itself by providing them quantitative, numerical models of how individuals learn.[78]
- Software that employs machine learning to detect patterns in written work, speech, and other actions could better adapt to students’ learning styles and needs.
- Ultimately, machine learning can enable students, faculty, and researchers to communicate more authentically with their devices. For example, a professor of an online course on artificial intelligence created a robot teaching assistant that learned to pull meaning from the way students write in order to answer their questions.[79]

Machine Learning in Practice

- Botanists at the Institute of Botany, Chinese Academy of Sciences collaborated with Microsoft Research Asia to develop a Smart Flower Recognition System by training a deep neural network to recognise images using a set of learnable filters: go.nmc.org/teamup.
- Shanxi Normal University Researchers made a machine learning algorithm available on a public web server so that anyone interested can perform their own prediction analysis of protein dephosphorylation: go.nmc.org/deph.
- Tsinghua University and Duke University created a Duke-Tsinghua Machine Learning Summer School with a focus on deep learning for big data: go.nmc.org/offer.

For Further Reading

Solving Verbal Questions in IQ Test by Knowledge-Powered Word Embedding (PDF)
go.nmc.org/solvingiq

(Wang et al., arxiv.org, 26 April 2016.) This paper describes how a deep learning model has allowed a machine to understand the meaning of words and relations among words using word embedding techniques. The machine out-performed human workers involved in the experiment in solving verbal comprehension questions in IQ Tests.

Why Machine-learning Will Enhance, Not Replace, Human Creativity
go.nmc.org/willenh

(Loni Stark, *The Next Web*, 11 May 2016.) Machine-learning technologies will increasingly assist humans with data processing, freeing them to focus on more thoughtful tasks, such as decision-making and leveraging creativity and empathy toward inventive designs, products, and services.

Time-to-Adoption: Four to Five Years

Robotics

Robotics refers to the design and application of robots — automated machines that accomplish a range of activities. The first robots were integrated into factory assembly lines to streamline manufacturing, most notably for cars, and have since begun to automate a growing number of processes for China's biggest exports, from mobile phones to air conditioners. This year, the Chinese government approved a five-year plan for China's economy that includes monetary support for manufacturers that upgrade to technologies including advanced machinery and robots.[80] Meanwhile, the global robot population is expected to double to four million by 2020 — a shift that will impact business models and economies worldwide,[81] with the market to be worth $135 billion in 2019.[82] While robotics is identified as four to five years away from mainstream use in Chinese higher education, local universities are ramping up their robotics programs to prepare graduates to innovate current processes in their fields, and to live and work in a world assisted by robots.

Relevance for Teaching, Learning, or Creative Inquiry

- Drones are a form of robots rising in popularity. The high demand in China for drone pilots is calling for more drone education offerings.[83]
- Multidisciplinary studies into technologies such as visual image, voice recognition, and motion control are elemental to the field of robotics, which is compelling universities to collaborate in cross-disciplinary and cross-institutional projects.[84]
- Robots can bolster productivity in China's workforce by undertaking jobs that are too monotonous for humans or that previously exposed human workers to health hazards.[85]

Robotics in Practice

- The Chinese University of Hong Kong is developing dexterous robots to assist physicians with tedious procedures: go.nmc.org/letbe.
- A collaboration between China University of Political Science and Law and the University of New Haven has resulted in the China-US Forensic Technology Research Centre where robots are being developed to enter crime scenes and provide police investigators with data such as ambient room temperature or details on the state of a body: go.nmc.org/forens.
- The RoboMasters National Undergraduate Robotics Competition annually brings students from universities worldwide together in Shenzhen to showcase their robotic inventions and compete for cash prizes: go.nmc.org/roboma.

For Further Reading

Artificial Intelligence and Robotics Slowly Enter College Classrooms
go.nmc.org/aislow

(Calvin Hennick, *EdTech Magazine*, 16 February 2015.) Robotic elements in both face-to-face and online learning environments assist instruction and provide tutoring support and personalised encouragement to students.

The Robots are Coming for the Professionals
go.nmc.org/forprof

(David Mathews, *Times Higher Education*, 28 July 2016.) The author argues that it is vital for universities to keep a pulse on how robotics and related technologies are progressing and affecting various fields, such as law and finance. Machines and software are mastering skills such as pattern recognition, making predictions, and developing content, but uniquely human skills including emotional intelligence, empathy, and higher level decision-making will be increasingly in demand from graduates.

Time-to-Adoption: Four to Five Years

Volumetric and Holographic Displays

One of the long anticipated innovations to stem from the rapid progression of technology has been holographic or volumetric displays, also referred to as 3D displays. Since the pioneering work done by MIT's Media Lab using a spatial light modulator in the creation of digital holography,[86] improvements on that design and new ways of creating holographic and volumetric displays have continued to develop.[87] Remaining technical challenges[88] and high cost are still factors in mainstream adoption, and will continue to be streamlined over the next few years. One possible solution to reducing cost and expanding use is open source holographic and volumetric display designs.[89] The holographic display market is predicted to reach $1.82 billion by 2021.[90] China is identified as one of the emerging markets expected to influence this growth.[91] Chinese researchers continue to add to the development and expansion of holographic and volumetric technologies such as the work being done by Shanghai University's Ultra-precision Optoelectronic Metrology and Information Display Technologies Research Centre.[92]

Relevance for Teaching, Learning, or Creative Inquiry

- Both students and faculty with physical disabilities can leverage volumetric and holographic displays to project their images, which can move around learning environments to more seamlessly collaborate with others.
- This technology can alleviate the barriers of distance to connect students and faculty with world experts through highly interactive, visual learning experiences.
- Volumetric and holographic displays can provide opportunities for students to express their creativity and enhance learning content by making it more engaging.

Volumetric and Holographic Displays in Practice

- Chinese gaming and online education company, NetDragon, is working with ARHT Inc., creator of the digital human holograms HumaGrams. This partnership will allow the foremost subject matter experts from around the world into previously unreachable areas throughout the Asia-Pacific region: go.nmc.org/netdrag.
- Hong Kong-based company Looking Glass introduced the glasses-free volumetric display "Volume." This device, considered a personal volumetric display, could serve as an entry to affordable displays: go.nmc.org/holog.
- Tsinghua University School of Medicine's Advanced Theranostics and 3D Imaging Laboratory's Integral Videography allows surgeons to view overlaid 3D autostereoscopic images of anatomical information with their naked eyes: go.nmc.org/ther.

For Further Reading

Introducing Holographic Telepresence: Is it the Future?
go.nmc.org/introholo
(SUMMIT, 3 March 2015.) Holographic telepresence refers to people or objects from another location being transported into the room from a remote location. This article explains how the technology works and discusses broad range implications.

Shrinking 3-D Technology for Comfortable Smartphone Viewing
go.nmc.org/shrin
(The Optical Society, 23 February 2016.) Researchers at Sun Yat-Sen University's State Key Lab of Optoelectronics Materials and Technology are designing compact 3D visual effects that do not cause viewer discomfort, making 3D displays on mobile platforms more viable.

Methodology

The process used to research and create the *2017 NMC Technology Outlook for Chinese Higher Education: A Horizon Project Regional Report* is very much rooted in the methods used throughout the NMC Horizon Project. All publications of the NMC Horizon Project are produced using a carefully constructed process that is informed by both primary and secondary research. Dozens of technologies, meaningful trends, and critical challenges are examined for possible inclusion in the report for each edition. Every report draws on the considerable expertise of an internationally renowned panel of experts that first considers a broad set of important developments in technology, challenges, and trends, and then examines each of them in progressively more detail, reducing the set until the final listing of trends, challenges, and important developments in educational technology is selected.

Much of the process takes place online, where it is captured and placed in the NMC Horizon Project wiki. This wiki, which has grown into a resource of hundreds of pages, is intended to be a completely transparent window onto the work of the project, and contains the entire record of the research for each of the various editions. The section of the wiki used for the *2017 NMC Technology Outlook for Chinese Higher Education* can be found at china.nmc.org.

The procedures for selecting the topics that are in this report include a modified Delphi process now refined over years of producing the *NMC Horizon Report* series, and it began with the assembly of the expert panel. The panel as a whole was intended to represent a wide range of backgrounds and interests, yet with each member bringing a particularly relevant expertise. To date, more than 2,000 internationally recognised practitioners and thought leaders have participated in the NMC Horizon Project Expert Panels.

Once the expert panel for a particular edition is constituted, their work begins with a systematic review of the literature — press clippings, reports, essays, and other materials — that pertains to emerging technology. Panel members are provided with an extensive set of background materials when the project begins, and are then asked to comment on them, identify those that seem especially worthwhile, and add to the set. The group discusses existing applications of emerging technology and brainstorms new ones. A key criterion for the inclusion of a topic is the potential relevance of the topic to teaching, learning, or creative inquiry. A selection of dozens of relevant publications ensures that background resources stay current as the project progresses. They are used to inform the thinking of the participants throughout the process.

Following the review of the literature, the expert panel engages in the central focus of the research — the research questions that are at the core of the NMC Horizon Project. These questions are designed to elicit a comprehensive listing of technology developments, trends, and challenges from the panel:

1. *Which of these important developments in technology will be most important to Chinese higher education within the next five years?*
2. *What important developments in technology are missing from our list? Consider these related questions:*
    a. *What would you list among the established technologies that some Chinese universities and educational programmes are using today that arguably ALL Chinese universities and educational programmes should be using broadly to support or enhance teaching, learning, or creative inquiry?*
    b. *What developments in technology that have a solid user base in consumer, entertainment, or other industries should Chinese universities and educational programmes be actively looking for ways to apply?*

   c. *What are the emerging technologies you see developing to the point that Chinese universities and educational programmes should begin to take notice during the next four to five years?*

3. *What key trends do you expect to accelerate the uptake of emerging technology across Chinese higher education?*
4. *What do you see as the significant challenges impeding emerging technology uptake across Chinese higher education?*

One of the expert panel's most important tasks is to answer these questions as systematically and broadly as possible, so as to ensure that the range of relevant topics is considered. Once this work is done, moves quickly over just a few days, the expert panel moves to a unique consensus-building process based on an iterative Delphi-based methodology.

The responses to the research questions are systematically ranked and placed into adoption horizons by each panel member using a multi-vote system that allows members to weight their selections. Each member is asked to also identify the timeframe during which they feel the technology would enter mainstream use — defined for the purpose of the project as about 20% of institutions adopting it within the period discussed. (This figure is based on the research of Geoffrey A. Moore and refers to the critical mass of adoptions needed for a technology to have a chance of entering broad use.) These rankings are compiled into a collective set of responses, and inevitably, the ones around which there is the most agreement are quickly apparent.

For additional detail on the project methodology or to review the instrumentation, the rankings, and the interim products behind the report, please visit the project wiki, which can be found at china.nmc.org.

2017 Horizon Project China Expert Panel

Samantha Adams Becker
Co-Principal Investigator
New Media Consortium

Yuan Gao
Project Manager
Beijing Normal University

Ronghuai Huang
Co-Principal Investigator
Beijing Normal University

Shuqiang Song
Researcher
Journal of Modern Educational Technology

Ting-Wen Chang
Researcher
Beijing Normal University

Xuefeng Wei
Researcher
Ludong University

Hao Bai
Shaanxi Normal University

Lei Bao
The Ministry of Education of the People's Republic of China

Emil Chen
NetDragon Websoft Inc.

Geng Chen
Beijing Jiaotong University

Song Chen
Nanjing College of Information Technology

Yonghong Chen
Blackboard China

Yan Dao
Sun Yat-Sen University

Weize Ding
Information Office of Nantong University

Rong Dong
Zhejiang University

Yang GaiXue
Northwest Normal University

Dongfeng Gao
The Ministry of Education of the People's Republic of China

Tiegang Gao
Liaoning Educational Technology Centre

Enjing Guan
Shandong University of Technology

Jiong Guo
Northwest Normal University

Mingzhou Guo
Lanzhou University

Jun Han
National Centre for Educational Technology

Shan He
Peking University

Huijun Hu
China Academy of Art

Shiqing Hu
Shenzhen University

Wei Huang
China Education Daily

Yuemin Huang
National Cheng Kung University

Yueming Huang
Wenzhou Educational Technology Centre

Dongxing Jiang
Tsinghua University

Liqiong Lan
Sichuan University

Hongfei Li
Central China Normal University

Maoguo Li
Chongqing University

Qing Li
Beijing University of Posts and Telecommunications

Shuangshou Li
Tsinghua iCentre

Xin Li
Journal of China Educational Technology

Zheng Li
Xi'an Eurasia University

Zhimin Li
The Ministry of Education of the People's Republic of China

Jianxiang Lin
Peking University

Geping Liu
Southwest University / Beijing Polytechnic

Chizhu Ma
Shandong Normal University

Rui Ning
The Ministry of Education of the People's Republic of China

Feiyue Qiu
Zhejiang University of Technology

Ren YouQun
East China Normal University

Jingrong Sha
Northwest University for Nationalities

Hongxing Shen
Shanghai Jiao Tong University

Junhui Shi
Education Bureau of Hong Kong

Zhiyuan Shi
Xiamen University

Weiping Sun
Blackboard China

Kan Tao
Distance Education Journal

Hao Wang
Pearson, China

Qiong Wang
Peking University

Peng Wang
Inner Mongolia University

Wei Wang
Shenyang Normal University

Xiaomei Wang
China Association of Higher Education

Yi Wang
Chaoxing Digital Group

Youmei Wang
Wenzhou University

Yun Wang
Shanxi Normal University

Shunping Wei
The Open University of China

Fati Wu
Beijing Normal University

Ying-tien Wu
National Central University

Lei Xing
Shanghai Jiaotong University

Xiaoyi Xu
South China Normal University

Zhiming Yan
Ludong University

Xiaojian Yang
Gansu Provincial Centre for Educational Technology

Xianmin Yang
Jiangsu Normal University

Zaishi Yang
Higher Education Press

Zhijian Yang
The Open University of China

Zongkai Yang
Central China Normal University

Baohua Yu
The Education University of Hong Kong

Shengquan Yu
Beijing Normal University

Donghai Zhai
Tencent Education

Caisheng Zhang
TianYu Educational Research Institute

Jianhua Zhang
Beihang University

Jianping Zhang
Zhejiang University

Jige Zhang
Lanzhou University

Junbin Zhang
Xi'an Jiaotong University

Liming Zhang
University of Macau

Xuewen Zhang
XinHua Digest

Zhi Zhang
Shanghai Educational Technology Centre

Chengling Zhao
Central China Normal University

Huichen Zhao
Henan University

Shaochun Zhong
Northeast Normal University

Xiaoliu Zhong
Tsinghua University

Zhiting Zhu
East China Normal University

End Notes

[1] http://www.nottingham.edu.cn/en/news/2016/unnc-launches-incubator-centre.aspx
[2] https://fossbytes.com/china-is-teaching-coding-much-much-earlier-than-the-u-s-and-india/
[3] http://www.imse.hku.hk/facilities/human-system-interaction-and-simulation-laboratory-his
[4] http://at3d.med.tsinghua.edu.cn/en/introduction/Overview.html
[5] http://www.nhregister.com/article/NH/20160126/NEWS/160129647
[6] http://www.moocchina.com.cn/
[7] https://www.researchgate.net/publication/297676527_Unobtrusive_and_Multimodal_Wearable_Sensors_to_Quantify_Anxiety
[8] http://219.225.128.73/meol//index.do
[9] http://www.hewlett.org/strategy/open-educational-resources/
[10] https://www.nsf.gov/news/news_summ.jsp?cntn_id=137394&org=NSF&from=news
[11] http://www.ctuas.com/Article/news/id/1460944354
[12] http://hechingerreport.org/while-liberal-arts-decline-in-u-s-china-and-other-economic-rivals-add-them/
[13] http://ipodia.usc.edu/about/
[14] https://www.kth.se/kth-tsinghua
[15] http://en.cnki.com.cn/Article_en/CJFDTOTAL-JFJJ201506006.htm
[16] https://www.linkedin.com/pulse/made-china-2025-internet-plus-4th-industrial-fies-kiran-patel-%E6%9C%B1%E4%BF%8A%E5%8D%9A-
[17] http://www.bjreview.com/Nation/201604/t20160408_800054149.html
[18] http://www.chinatechinsights.com/analysis/16020837.html
[19] http://www.china.org.cn/top10/2015-06/16/content_35831348.htm
[20] http://www.huffingtonpost.com/entry/inside-a-chinese-coding-boot-camp_us_5682794ee4b0b958f65a59e0
[21] https://www.techinasia.com/liu-yi-profile-cto-1ke
[22] http://knowledge.ckgsb.edu.cn/2015/12/08/employment/the-wizards-of-zhongguancun-and-the-rise-of-online-vocational-schools-in-china/
[23] http://www.worldbank.org/en/results/2015/09/14/china-improving-technical-and-vocational-education-to-meet-the-demand-for-high-skilled-workers
[24] http://www.china.org.cn/english/13777.htm
[25] http://www.xnjd.cn/en/news/SelfStudy.htm
[26] http://www.forbes.com/sites/jordanshapiro/2015/10/31/five-technology-fundamentals-that-all-kids-need-to-learnnow/#1a712e397c8c
[27] http://blog.core-ed.org/blog/2015/10/what-is-digital-fluency.html
[28] http://www.digitalcitizenship.net/Nine_Elements.html
[29] http://www.sixthtone.com/news/how-wechat-changing-online-learning-we-know-it
[30] http://ie.china-embassy.org/eng/whjy/educationdevelopment/t112961.htm
[31] http://china.nmc.org/index.php/Rq4
[32] http://edglossary.org/personalized-learning/
[33] http://thediplomat.com/2016/09/china-the-new-world-leader-in-mobile-technology/
[34] http://www.downes.ca/post/65519
[35] http://ec.europa.eu/assets/eac/youth/events/documents/entrepreneurship-entrepreneurship-education-china-liufan_en.pdf (PDF)
[36] https://fossbytes.com/china-is-teaching-coding-much-much-earlier-than-the-u-s-and-india/
[37] http://www.flippedclassroomworkshop.com/flipping-control-to-your-students/
[38] http://www.jonbergmann.com/the-flipped-classroom-explained/
[39] https://www.panopto.com/blog/7-unique-flipped-classroom-models-right/
[40] http://www.edudemic.com/flipped-classrooms-2/
[41] http://flglobal.org/flippedresearchlabs/
[42] https://www.makerspaces.com/what-is-a-makerspace/
[43] http://confuciusmag.com/entrepreneurs-china-starts-up
[44] http://news.xinhuanet.com/english/2016-02/19/c_135111035.htm
[45] http://www.chinadaily.com.cn/china/2015-06/29/content_21127750_2.htm
[46] http://moocnewsandreviews.com/a-short-history-of-moocs-and-distance-learning/
[47] http://asemlllhub.org/fileadmin/www.asem.au.dk/publications/MOOCs_and_Educational_Challenges_around_Asia_and_Europe_FINAL.pdf (PDF)
[48] https://www.edsurge.com/news/2016-06-30-looking-to-grow-in-china-3-lessons-for-u-s-edtech-companies
[49] http://tl.hku.hk/hkuonline/
[50] http://tnet1.theti.org/evaluate/DSS_DD/infoSingleArticle.do?articleId=1340038&columnId=306708
[51] https://thejournal.com/Articles/2016/07/05/Mobile-Learning.aspx?Page=1
[52] https://techcrunch.com/2017/01/23/china-internet-half-population-mobile/
[53] http://techwireasia.com/2016/07/qoocos-david-topolewski-education-china/
[54] http://link.springer.com/article/10.1007/s40692-015-0043-0
[55] http://www.ijlass.org/data/frontImages/gallery/Vol._4_No._5/14._109-114.pdf (PDF)
[56] https://www.edsurge.com/news/2015-09-07-how-virtual-reality-can-close-learning-gaps-in-your-classroom
[57] http://2015.aweasia.com/ar-in-china/

[58] http://venturebeat.com/2016/07/03/virtual-reality-heats-up-in-china/
[59] http://www.bjreview.com/Nation/201604/t20160408_800054149.html
[60] https://www.jisc.ac.uk/reports/learning-analytics-in-higher-education
[61] https://library.educause.edu/~/media/files/library/2016/2/ers1504la.pdf (PDF)
[62] https://www.mheducation.com/ideas/three-levels-learning-analytics-adaptive-learning.html
[63] http://gccce2016.ied.edu.hk/c7.html
[64] https://www.wareable.com/wearable-tech/contenders-chasing-chinas-health-fitness-boom-887
[65] http://asia.nikkei.com/magazine/20160616-POWER-PERFORMERS-of-the-Asia300/Tea-Leaves/Will-self-quantification-conquer-the-selfie
[66] http://www.gfk.com/fileadmin/user_upload/website_content/Images/Global_Study/Fitness_tracking/Documents/20160929_PR-study_Monitoring-health-fitness_press_release_vfinal.pdf (PDF)
[67] http://www.opencolleges.edu.au/informed/features/quantified-self-and-the-future-of-personalised-learning/
[68] http://www.theedadvocate.org/4-benefits-of-virtual-labs/
[69] https://repositorio.itesm.mx/ortec/bitstream/11285/615968/1/2016-Ramirez-Ramirez-Marrero.pdf (PDF)
[70] http://www.edtechmagazine.com/higher/article/2014/08/colleges-see-benefits-remote-labs
[71] http://affect.media.mit.edu/
[72] http://en.nwpu.edu.cn/info/1003/1475.htm
[73] https://www.polyu.edu.hk/cpa/excel/en/201506/viewpoint/v1/index.html
[74] http://www.sciencedirect.com/science/article/pii/S0747563215001417?np=y
[75] http://www.mlplatform.nl/what-is-machine-learning/
[76] https://www.washingtonpost.com/news/the-switch/wp/2016/10/13/china-has-now-eclipsed-us-in-ai-research/?utm_term=.c4e98047ec12
[77] https://www.technologyreview.com/s/600993/can-machine-learning-help-lift-chinas-smog/
[78] http://nautil.us/issue/40/learning/teaching-me-softly-rp
[79] http://www.theverge.com/2016/5/6/11612520/ta-powered-by-ibm-watson
[80] https://www.technologyreview.com/s/601215/china-is-building-a-robot-army-of-model-workers/
[81] https://hbr.org/2015/06/the-age-of-smart-safe-cheap-robots-is-already-here
[82] http://fortune.com/2016/02/24/robotics-market-multi-billion-boom/
[83] http://phys.org/news/2016-01-drone-schools-china-field-sector.html.
[84] http://www.forbes.com/sites/linyang/2016/08/17/inside-a-chinese-entrepreneurs-robot-dream/2/#409997bf38bb
[85] http://www.businessinsider.com/robotics-in-china-2015-11
[86] https://dspace.mit.edu/bitstream/handle/1721.1/62363/50529489-MIT.pdf?sequence=2
[87] http://www.sky-technology.eu/en/blog/article/item/6-fascinating-future-display-technologies.html
[88] http://www.photonics.com/Article.aspx?AID=58372
[89] http://www.3ders.org/articles/20151217-volumetric-displays-re-imagined-with-3d-printed-double-helix.html
[90] http://industryarc.com/Report/15041/holographic-display-market.html
[91] http://www.marketwatch.com/story/holographic-display-market-to-reach-182-billion-usd-by-2021-driven-mainly-by-growth-of-commercial-and-medical-industry-in-americas---industryarc-analysis-2016-07-28-10203313
[92] http://cpb.iphy.ac.cn/article/2016/1846/cpb_25_9_094203.html

The New Media Consortium
Sparking innovation, learning, and creativity

1250 Capital of Texas Hwy South
Building 3, Suite 400
Austin, TX 78746

tel 512 445-4200
fax 512 445-4205
web www.nmc.org

ISBN 978-0-9986242-0-4